WE CLAIM:

1. An improved method for optimizing wheel slip of a land or aircraft vehicle with respect to a ground surface to maximize braking performance of a wheel-mounted tire against a ground surface during application of the wheel brake by an operator of the vehicle comprising:

measuring wheel angular speed;

processing the measured wheel angular speed in a sliding mode observer to calculate an estimated differential wheel torque, wherein said differential wheel torque represents the difference between wheel drag torque, generated at the interface of the tire and the ground surface, and applied braking torque;

generating a threshold differential wheel torque from measured wheel angular speed;

generating a braking control signal from comparison of the estimated differential wheel torque and the threshold differential wheel torque; and

applying the braking control signal to a brake actuator as an applied braking torque so as to optimize wheel slip during braking.

2. The method of Claim 1, wherein the brake actuator is responsive to an off-command braking control signal by interrupting the application of the wheel brake by the vehicle operator and is responsive to an on-command braking control signal by not interrupting the application of the wheel brake by the vehicle operator, and wherein:

the step of generating the braking control signal comprises generating an off-command braking control signal whenever the generated differential wheel torque is less than the threshold differential wheel torque and an on-command braking control signal whenever the generated differential torque is greater than the threshold differential wheel torque.

3. The method of Claim 2, wherein the applying step comprises converting the braking control signal into a scaled analog actuator control current by low pass filtering to smooth the on-command braking control signal and the off-commands braking control signal such that the applied braking torque generated by the actuator to alter the wheel slip is, or

rapidly approaches, zero whenever the braking control signal exhibits the off-command and is, or rapidly approaches, a non-zero value whenever the braking control signal exhibits the on-command.

4. The method of Claim 3, wherein the braking actuator is one of an electro-mechanical brake actuator and an hydraulic brake actuator.

5. The method of Claim 2, wherein the braking actuator is one of an electro-mechanical brake actuator and an hydraulic brake actuator.

6. The method of Claim 2, wherein the brake actuator comprises one of a electro-mechanical and an hydraulic brake actuator and further comprising:

measuring the force of application of the wheel brake by the operator and developing a force signal in response; and

limiting the maximum brake torque available to be applied to the wheel by the brake actuator in proportion to the measured force so that full operator applied force is required to generate maximum available brake torque when the braking control signal exhibits the on-command.

7. The method of Claim 1, wherein the step of generating a threshold differential wheel torque comprises selecting a fixed threshold differential wheel torque appropriate to the vehicle.

8. The method of Claim 1, wherein the step of generating a variable threshold differential wheel torque comprises:

generating a skid signal from the measured wheel angular speed that is at zero in the absence of wheel slip and is at a numeric value proportional to wheel slip when wheel slip occurs;

determining whether the skid signal is increasing, signifying increasing wheel slip, and increasing the threshold differential wheel torque favoring reduced braking in response thereto; and

determining whether the skid signal is decreasing, signifying decreasing wheel slip, and decreasing the threshold differential wheel torque favoring increased braking in response thereto.

9. The method of Claim 8, wherein the measured wheel angular speed exhibits speed amplitude peaks and valleys with intermittent changes in wheel slip, and the step of generating a skid signal comprises:

defining a moving time window;

detecting a plurality of the peaks and/or the valleys of the wheel angular speed over the moving time window;

determining a smoothed version of the maximum wheel angular speed from the plurality of peaks via averaging or filtering and/or determining a smoothed version of the minimum wheel angular speed from the plurality of valleys via averaging or filtering;

deriving a reference vehicle velocity from knowing that the smoothed maximum wheel angular speed must be associated with a minimal value of instantaneous slip and/or the smoothed minimum wheel angular speed must be associated with a maximal value of instantaneous wheel slip; and

deriving the skid signal from the derived reference vehicle velocity and the measured wheel angular speed proportional to the instantaneous wheel slip.

10. The method of Claim 8, further comprising providing a lookup table of adjustments to the threshold differential wheel torque, the look-up table using the current value of the differential wheel torque threshold and the determined skid signal.

11. The method of Claim 1, wherein the step of generating a braking control signal comprises:

generating the off-command braking control signal that commands the brake actuator to interrupt application of the brake to the wheel when the estimated differential wheel torque falls below the threshold differential wheel torque; and

generating the on-command braking control signal that does not command the actuator to interrupt application of the brake to the wheel when the estimated differential wheel torque falls below the threshold differential wheel torque.

12. The method of Claim 11, wherein:

the wheel brake comprises one of a master cylinder and an accumulator that develops a hydraulic pressure during application of the wheel brake by the vehicle operator that is applied to the brake actuator that responds by applying braking force to the wheel in proportion to hydraulic pressure; and

the brake actuator incorporates a pressure regulator that allows the actuator to regulate the maximum hydraulic pressure to the brake cylinder to any intermediate value between zero and the maximum available from the master cylinder or accumulator, and

further comprising the steps of:

generating a pressure modulation control signal for driving the pressure regulator valve so as to vary the maximum available hydraulic pressure that can be applied to the brake actuator; and

applying the braking pressure modulation control signal to the pressure regulator to modulate the hydraulic pressure applied to the wheel when the brake control signal exhibits the on-command, the maximum available hydraulic pressure in turn determining the maximum applied brake torque.

13. The method of Claim 11, wherein the wheel brake actuator comprises an electro-mechanical actuator that applies braking force directly to the wheel in proportion to an electrical current input to the wheel brake actuator during application of the wheel brake by the vehicle operator, and further comprising the steps of:

generating a current modulation control signal to vary the maximum available electrical current that can be input to the brake actuator, the maximum available electrical current determining the maximum applied brake torque; and

applying the braking current modulation signal to the electro-mechanical actuator to modulate the maximum brake torque applied to the wheel when the braking control signal exhibits the on-command.

14. The method of Claim 1, wherein the vehicle is an aircraft, and the wheel and tire are mounted to a strut that exhibits fore-aft gear-walk acceleration while the tire is in contact with the ground surface, and further comprising:

measuring fore-aft acceleration of the strut and providing an acceleration signal;

processing the acceleration signal to develop a gear walk suppression signal; and

combining the gear walk suppression signal with the braking control signal to achieve both antilock brake function as well as gear walk suppression.

15. An improved method for optimizing wheel slip of a land or aircraft vehicle with respect to a ground surface to maximize braking performance of a tire against a ground surface during application of the wheel brake by an operator of the vehicle comprising:

measuring both wheel angular speed and applied braking torque;

processing the measured wheel angular speed in a sliding mode observer to calculate an estimated differential wheel torque, wherein said differential wheel torque represents the difference between drag torque, generated at the interface of the tire and the ground surface, and applied braking torque;

combining the estimated differential wheel torque with the measured applied torque to obtain an estimated wheel drag torque; and

regulating the applied brake torque as a function of estimated wheel drag torque to maximize estimated wheel drag torque.

16. A system for optimizing wheel slip of a land or aircraft vehicle with respect to a ground surface to maximize braking performance of a wheel-mounted tire against a ground surface during application of the wheel brake by an operator of the vehicle comprising:

means for measuring wheel angular speed;

means for processing the measured wheel angular speed in a sliding mode observer to calculate an estimated differential wheel torque, wherein said differential wheel torque represents the difference between wheel drag torque, generated at the interface of the tire and the ground surface, and applied braking torque;

means for generating a threshold differential wheel torque from measured wheel angular speed;

means for generating a braking control signal from comparison of the estimated differential wheel torque and the threshold differential wheel torque; and

means for applying the braking control signal to a brake actuator as an applied braking torque so as to optimize wheel slip during braking.

17. The system of Claim 16, wherein the brake actuator is responsive to an off-command braking control signal by interrupting the application of the wheel brake by the vehicle operator and is responsive to an on-command braking control signal by not interrupting the application of the wheel brake by the vehicle operator, and wherein:

the means for generating the braking control signal comprises means for generating an off-command braking control signal whenever the generated differential wheel torque is less than the threshold differential wheel torque and an on-command braking control signal

whenever the generated differential torque is greater than the threshold differential wheel torque.

18. The system of Claim 17, wherein the applying means comprises means for converting the brake control signal into a scaled analog actuator control current by low pass filtering to smooth the on-command and off-commands of the braking control signal such that the applied braking torque generated by the actuator to alter the wheel slip is, or rapidly approaches, zero whenever the braking control signal exhibits the off-command and is, or rapidly approaches, a non-zero value whenever the braking control signal exhibits the on-command.

19. The system of Claim 18, wherein the braking actuator is one of an electro-mechanical brake actuator and an hydraulic brake actuator.

20. The system of Claim 18, wherein the braking actuator is one of an electro-mechanical brake actuator and an hydraulic brake actuator.

21. The system of Claim 17, wherein the brake actuator comprises one of a electro-mechanical and an hydraulic brake actuator and further comprising:

means for measuring the force of application of the wheel brake by the operator and developing a force signal in response; and

means for limiting the maximum brake torque available to be applied to the wheel by the brake actuator in proportion to the measured force so that full operator applied force is required to generate maximum available brake torque when the braking control signal exhibits the on-command.

22. The system of Claim 16, wherein the means for generating a threshold differential wheel torque comprises selecting a fixed threshold differential wheel torque appropriate to the vehicle.

23. The system of Claim 16, wherein the means for generating a variable threshold differential wheel torque comprises:

means for generating a skid signal from the measured wheel angular speed that is at zero in the absence of wheel slip and is at a numeric value proportional to wheel slip when wheel slip occurs;

means for determining whether the skid signal is increasing, signifying increasing wheel slip, and increasing the threshold differential wheel torque favoring reduced braking in response thereto; and

means for determining whether the skid signal is decreasing, signifying decreasing wheel slip, and decreasing the threshold differential wheel torque favoring increased braking in response thereto.

24. The system of Claim 23, wherein the measured wheel angular speed exhibits speed amplitude peaks and valleys with intermittent changes in wheel slip, and the means for generating a skid signal comprises:

means for detecting a plurality of the peaks and/or the valleys of the wheel angular speed over a moving time window;

means for determining a smoothed version of the maximum wheel angular speed from the plurality of peaks via averaging or filtering and/or determining a smoothed version of the minimum wheel angular speed from the plurality of valleys via averaging or filtering;

means for deriving a reference vehicle velocity from knowing that the smoothed maximum wheel angular speed must be associated with a minimal value of instantaneous slip and/or the smoothed minimum wheel angular speed must be associated with a maximal value of instantaneous wheel slip; and

means for deriving the skid signal from the derived reference vehicle velocity and the measured wheel angular speed proportional to the instantaneous wheel slip.

25. The method of Claim 23, further comprising a lookup table of adjustments to the threshold differential wheel torque, the look-up table using the current value of the differential wheel torque threshold and the determined skid signal.

26. The system of Claim 16, wherein the means for generating a braking control signal comprises:

means for generating a braking control signal off command that commands the brake actuator to interrupt application of the brake to the wheel when the estimated differential wheel torque falls below the threshold differential wheel torque; and

means for generating a braking control signal on-command that does not command the actuator to interrupt application of the brake to the wheel when the estimated differential wheel torque falls below the threshold differential wheel torque.

27. The system of Claim 16, wherein:

the wheel brake comprises one of a master cylinder and an accumulator that develops a hydraulic pressure during application of the wheel brake by the vehicle operator that is applied to the brake actuator that responds by applying braking force to the wheel in proportion to hydraulic pressure; and

the brake actuator incorporates a pressure regulator that allows the actuator to regulate the maximum hydraulic pressure to the brake cylinder to any intermediate value between zero and the maximum available from the master cylinder or accumulator, and

further comprising:

means for generating a pressure modulation control signal for driving the pressure regulator valve so as to vary the maximum available hydraulic pressure that can be applied to the brake actuator; and

means for applying the braking pressure modulation control signal to the pressure regulator to modulate the hydraulic pressure applied to the wheel when the brake control signal exhibits the on-command, the maximum available hydraulic pressure in turn determining the maximum applied brake torque.

28. The system of Claim 16, wherein the wheel brake actuator comprises an electro-mechanical actuator that applies braking force directly to the wheel in proportion to an electrical current input to the wheel brake actuator during application of the wheel brake by the vehicle operator, and further comprising:

means for generating a current modulation control signal to vary the maximum available electrical current that can be input to the brake actuator, the maximum available electrical current determining the maximum applied brake torque; and

means for applying the braking current modulation signal to the electro-mechanical actuator to modulate the maximum brake torque applied to the wheel when the braking control signal exhibits the on-command.

29. The system of Claim 16, wherein the vehicle is an aircraft, and the wheel and tire are mounted to a strut that exhibits fore-aft gear-walk acceleration while the tire is in contact with the ground surface, and further comprising:

means for measuring fore-aft acceleration of the strut and providing an acceleration signal;

means for processing the acceleration signal to develop a gear walk suppression signal; and

means for combining the gear walk suppression signal with the braking control signal to achieve both antilock brake function as well as gear walk suppression.